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THE POWER OF A SELF-PACED, CHALLENGING, PROCESS-BASED, ONLINE MATHEMATICS CURRICULUM FOR TALENTED MIDDLE SCHOOL STUDENTS

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Talented middle school students in most public schools and traditional private schools do not have access to a curriculum that allows them to go at their own pace, adequately challenges them, or presents mathematics in a process-based way so that students can become familiar with behaviors of mathematicians (Gentry, Gable, & Springer, 2000; Rogers, 2007). Many gifted students are subjected to materials written at levels that are inappropriate for them and teachers that are not adequately prepared to teach them (Rogers, 2007).

Talented students often become disengaged and may even become discipline problems when they are not given the chance to work at their own pace (Gentry, et al., 2000; Rogers, 2007). Many talented students see single-pace classes (even accelerated classes) as less productive and less enjoyable (Vialle, Ashton, & Carlton, 2001). Students in Vialle, et al.'s (2001) study remarked that they liked working independently “without the teacher interrupting” and that they don't “stare out the window so much” (p. 8). Rogers (2007) found that not only do gifted students prefer autonomy, they actually find it stressful to be in situations where the learning isn't progressing according to their individualized needs.

Neither acceleration nor testing out of content is the best solution. Talented students who are allowed to skip content or move up grade levels in school often report returning to the same level of boredom within 6-10 weeks of beginning the new level (Vialle et al., 2001). In addition to allowing students to work at their own pace, sufficient challenge must be provided and the environment must feel as if there are no ceilings on learning (Rogers, 2007).

Most mathematics textbooks provide little challenge to gifted students (Gentry, et al., 2000). Rogers (2007) found that half of the content in most mathematics curricula can be eliminated for talented learners with no negative effects on student achievement. Howley, Pendarvis, and Gholson (2005) state that schools “provide instruction that prepares few students for advanced” mathematics and therefore, few middle school students are “afforded experiences that position them to pursue...careers in mathematics or science” (p. 128). Talented learners require daily challenges that are authentic, increase motivation, and develop higher-order thinking skills (Diezmann & Watters, 2005).

Challenge is essential for deep understanding. Vygotsky's (1930-1934/1978) theory about the “Zone of Proximal Development” found that keeping instruction just ahead of a student's developmental level is of critical importance. Talented students also report more enjoyment of challenging curricula (Howley, et al., 2005).

Mathematics is more than just rules and procedures. According to NCTM (2000), understanding the processes of mathematics (problem-solving, representation, making connections, reasoning, and communication) is key to deep mathematical learning. It is critical for middle grades students to develop “habits of thinking” that mimic the habits of mind of practicing mathematicians

(Driscoll, 1999). Baroody and Niskayuna (1993) argue that a problem-solving approach which centers on the processes of mathematical inquiry is key to fostering the development of mathematical understanding. Using inquiry and problem-solving strategies leads to deeper understandings in talented students (Rogers, 2007). Moreover, students who use process-based curricula have more positive and diverse beliefs about the nature of mathematics (Howley, et al., 2005).

Hrina-Treharn (2011) states that the research of talented students' attitudes about mathematics is “limited and lacking” (p. 6). One of the few studies on the matter is that of Howley, Pendarvis, and Gholson (2005), which found that talented students do not have very positive or nuanced views of mathematics. “Far from seeing mathematics as a way of expressing ideas or as a method for characterizing relationships and patterns, these gifted children instead saw mathematics principally as a set of procedures with numbers – as calculations and algorithms” (Howley, et al., 2005, p. 138).

What students believe about the nature and role of mathematics is critical to their learning of mathematics, as negative beliefs stunt children's curiosity about mathematics and cause student motivations to learn mathematics to be based on grades and other extrinsic motivators (Howley, et al., 2005). Learning is not just an accumulation of facts. For meaningful learning to take place, students must have access to a challenging, process-based curriculum that is differentiated for their learning needs and exposes them to the authentic behaviors of a mathematician so that they can form deeper understandings of mathematics concepts and the nature of mathematics.

At this point in time, no controlled studies have been completed that explore the effects of the use of self-paced, challenging, process-based curricula on talented students’ beliefs about mathematics. If we expose gifted middle school students to self-paced, challenging, process-based curricula, we may change their beliefs about mathematics (Rogers, 2007). This research seeks to establish whether there is a relationship between students’ beliefs about mathematics and their images of a self-paced, challenging, process-based curriculum.

Background

In the 1960s a talented team of curriculum developers began to create the curriculum that is today known as *Elements of Mathematics: Foundations* (*EMF*) (IMACS, 2006). The founders of *EMF* began with the process-based view that doing mathematics involved reasoning, making connections, problem-solving, representation, and communication – the behaviors of a mathematician – and developed a curriculum that was consistent with what NCTM (2000) would later call the “Process Standards for Mathematics” and what the Common Core State Standards (CCSSI, 2010) would later term the “Standards for Mathematical Practice.” Through the Ford Foundation, U.S. Office of Education, and Central

Midwestern Regional Educational Laboratory (CEMREL) funding, the curriculum was developed and the first students started to use it in 1966 (IMACS, 2006). Today, there are classes using the paper textbook version of the curriculum with a face-to-face delivery model.

Starting in 2012, the self-paced, online version of the curriculum became available and is now in use by several school districts and by individual students from around the globe (IMACS, 2018). The mathematics content is presented in an integrated way and it addresses all of the Florida state and national standards for Prealgebra, Algebra 1, Algebra 2, Geometry, Trigonometry, and Precalculus; it also includes many topics that are not part of the traditional K-12 mathematics curriculum. There are 18 content courses as well as some supplemental courses that prepare students for standardized testing. Beginning in the summer of 2015, a large suburban district in Southeast Florida adopted the *EMF* curriculum for its most talented middle school mathematics students.

Research Questions & Methodology

The following research questions guided the research:

1. What beliefs do talented middle school students have about mathematics?
2. What beliefs do talented middle school students have about a self-paced, challenging, process-based curriculum?
3. What is the relationship between talented middle school students' beliefs about a self-paced, challenging, process-based curriculum and their images of mathematics?

To explore the research questions, a non-experimental, survey research design was employed. The respondents are 39 gifted sixth grade students from a large suburban district in Southeast Florida. The survey items about the nature of mathematics and mathematics education were used previously on studies about teachers' images of mathematics (Goodwin, 2010; Goodwin, Bowman, Wease, Keys, Fullwood, & Mowery, 2014).

Results

Demographics

Of the 39 student survey respondents, about 73% of the students were boys. Roughly 89% of the students are 12 years old. The average student reported that they were “confident” in their mathematical abilities. The average student reported that their grades in mathematics in the previous school year were “Straight As” and their grades in other subjects that year were also “Straight As.”

The students reported that they spent 31-60 minutes on mathematics homework and watching TV each night, 61-90 minutes on reading and homework in all subjects daily, and 91-120 minutes on electronic devices each day. The average student agreed with the statement “I have enough time to complete all my homework each night.”

About 84% of students declared mathematics as one of their favorite subjects. Science and music were also chosen as favorite subjects by about 63% and 55% of the students, respectively. Physical education and world languages were the least likely to be chosen as a favorite subject, with only about 21% of students choosing these subjects.

Beliefs about Mathematics

An overall image of mathematics item asks the student "Ideally, doing mathematics is like: cooking a meal, conducting an experiment, playing a game, doing a puzzle, doing a dance, or climbing a mountain." The most popular response by far was "doing a puzzle" with almost three-quarters of the responses. "Doing a dance" was not chosen by any students.

The students showed very positive beliefs about mathematics. Students most strongly agreed with the statements "Mathematics supports many different ways of looking at and solving the same problems," "Mathematics makes a unique contribution to human knowledge," "Math is thought provoking," and "Math is intricately connected to the real world." Students also agreed with the statements "Mathematics is fun," "In mathematics, you can be creative," and "The process of trying to prove a mathematical relationship can change your mind about it."

The age of the student was statistically significantly related to level of agreement with the statements "Mathematics supports many different ways of looking at and solving the same problems" ($t(35) = 2.94$, $p = .01$), "Math is intricately connected to the real world" ($t(35) = 3.81$, $p = .00$), and "In mathematics you can be creative" ($t(35) = 5.85$, $p = .00$). Those who were younger than 12 years old agreed more strongly with these statements than did their 12-year-old counterparts.

Whether mathematics is listed as a favorite subject or not was significantly related to agreement levels with the statements "Mathematics is fun" ($t(37) = -5.15$, $p = .00$) and "In mathematics, you can be creative" ($t(37) = -3.73$, $p = .00$). Those who listed mathematics as a favorite subject reported that they "strongly agreed" with the statement "Mathematics is fun" on average, while those who didn't "slightly disagreed" on average. Those who listed mathematics as a favorite subject reported that they "slightly agree" with the statement "In mathematics, you can be creative" on average, while those who didn't "slightly disagreed" on average. Reported level of confidence in mathematical abilities is significantly positively correlated with level of agreement with the statement "Mathematics is fun" ($r(38) = .45$, $p = .01$).

Responses on the item "Ideally, mathematics is like" were statistically significantly related to whether a student reported mathematics as a favorite subject (χ^2 (1, N = 39) = 9.38, $p = .00$). About 84% of those students who said one of their favorite subjects was mathematics selected "doing a puzzle" on the item

"Ideally, mathematics is like" while only roughly 29% of those students who did not say that mathematics was one of their favorite subjects picked "doing a puzzle."

The amount of time spent watching TV every night is significantly negatively correlated with their agreement with the statement "Math is thought provoking" ($r(39) = -.34$, $p = .03$).

Images of EMF

About 82% reported that their confidence in their mathematics abilities had improved since beginning *EMF*. The average student strongly agreed that "*EMF* is challenging," "*EMF* has made me more ready for high school than I would have been without *EMF*," and "*EMF* has made me more ready for college than I would have been without *EMF*."

Reported levels of enjoyment of *EMF* and other mathematics programs were significantly different ($t(38) = 2.66$, $p = .01$). The average student reported enjoying *EMF* at higher levels than they reported enjoying other mathematics programs. The students agreed that *EMF* has improved their ability to analyze complex problems, their self-study skills, their ability to focus for extended periods of time, and their confidence with respect to challenging programs.

Relationships between Beliefs about Mathematics and Images of EMF

Level of agreement with the statement "Mathematics is fun" is significantly positively correlated with level of agreement with the statements "I enjoy doing the *EMF* program" ($r(39) = .65$, $p = .00$) and "I enjoy doing other mathematics programs..." ($r(39) = .37$, $p = .02$).

Level of agreement with the statement "I enjoy doing the *EMF* program" is also significantly positively correlated with level of agreement with the statements "Mathematics supports many different ways of looking at and solving the same problems" ($r(39) = .44$, $p = .01$), "Mathematics makes a unique contribution to human knowledge" ($r(39) = .47$, $p = .00$), and "In mathematics, you can be creative" ($r(39) = .39$, $p = .02$).

Responses on the item that asked if *EMF* has improved confidence in mathematical abilities were significantly related to agreement levels with the statements "Mathematics is fun" ($t(36) = -4.56$, $p = .00$) and "In mathematics, you can be creative" ($t(36) = -3.73$, $p = .00$). Those who said that *EMF* improved their confidence in their mathematical abilities reported that they "strongly agreed" with the statement "Mathematics is fun" on average, while those who didn't "slightly disagreed" on average. Those who said that *EMF* improved their confidence in their mathematical abilities reported that they "slightly agree" with the statement "In mathematics, you can be creative" on average, while those who didn't "slightly disagreed" on average.

Responses on the item "Ideally, mathematics is like" were statistically significantly related to views about whether *EMF* improved confidence in mathematical abilities (χ^2 (1, N = 38) = 5.32, *p* = .02). Almost 90% of those who said "doing a puzzle" found *EMF* improved their confidence in their mathematical abilities while only about 56% of those who said something other than "doing a puzzle" reported that *EMF* improved their confidence in their mathematical abilities.

Perceived level of improvement in self-study skills due to *EMF* is significantly positively correlated with level of agreement with the statement "In mathematics, you can be creative" (*r*(37) = .36, *p* = .03). Perceived level of improvement in the ability to focus for extended periods of time due to *EMF* is significantly positively correlated with level of agreement with the statements "Mathematics is fun" (*r*(37) = .45, *p* = .01) and "In mathematics, you can be creative" (*r*(37) = .37, *p* = .03). Perceived level of improvement in confidence with respect to challenging programs due to *EMF* is significantly positively correlated with level of agreement with the statements "Mathematics is fun" (*r*(37) = .49, *p* = .00) and "In mathematics, you can be creative" (*r*(37) = .45, *p* = .01).

Responses on the item "Ideally, mathematics is like" were statistically significantly related to the reported level of challenge by *EMF* (*t*(37) = 2.04, *p* = .05). Those who said something other than "doing a puzzle" found *EMF* more challenging than those who said "doing a puzzle" The average "doing a puzzle" respondent was in the middle between "slightly agreeing" and "strongly agreeing" with the statement "*EMF* is challenging," while the average non-"doing a puzzle" respondent strongly agreed with the statement.

Responses on the item "Ideally, mathematics is like" were statistically significantly related to the reported change in confidence with respect to challenging programs (*t*(35) = -2.21, *p* = .03). Those who said "doing a puzzle" found *EMF* helped them gain more confidence with respect to challenging programs than those who said something other than "doing a puzzle." The average "doing a puzzle" respondent said their confidence with respect to challenging programs "is much stronger now," while the average non-"doing a puzzle" respondent said their confidence with respect to challenging programs "is slightly stronger now."

Level of agreement with the statement "*EMF* has made me more ready for high school than I would have been without *EMF*" is significantly positively correlated with level of agreement with the statements "Mathematics is fun" (*r*(39) = .48, *p* = .00), "Math is thought provoking" (*r*(39) = .47, *p* = .00), "Mathematics makes a unique contribution to human knowledge" (*r*(39) = .50, *p* = .00), and "Mathematics supports many different ways of looking at and solving the same problems" (*r*(39) = .50, *p* = .00).

Level of agreement with the statement "*EMF* has made me more ready for college than I would have been without *EMF*" is significantly positively correlated with level of agreement with the statements “Mathematics is fun” (r(38) = .44, p = .01), “Mathematics makes a unique contribution to human knowledge” (r(38) = .52, p = .00), and “Mathematics supports many different ways of looking at and solving the same problems” (r(38) = .50, p = .00).

Discussion of Findings

Overall, these talented students expressed positive views of mathematics. They strongly agreed that mathematics is thought-provoking, makes a unique contribution to human knowledge, connected to the real world, and supports many different ways of looking at and solving problems.

The students found *EMF* to be gratifying and challenging. Most reported that *EMF* better prepared them for high school and college mathematics courses than an accelerated, traditional curriculum and that *EMF* improved their self-study skills, ability to analyze complex problems and focus for extended periods of time, and confidence with respect to challenging programs.

Overall, the students who found *EMF* most enjoyable and rewarding, reported that *EMF* had improved their confidence, further developed their ability to focus and their self-study skills, and had made them more ready for future mathematics courses had more positive views of mathematics. Many statistically significant relationships between gifted middle school students’ images of mathematics and their opinions on a self-paced, challenging, process-based curriculum were uncovered.

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